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INVESTIGATION OF MICROSTRUCTURE OF AA7075 ALLOYS AFTER SEVERE PLASTIC DEFORMATION APPLICATION

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ABSTRACT

The aim of this study is to investigate the change of microstructural properties of AA7075 alloys after severe plastic deformation. Severe Plastic Deformation is a process used to improve the properties of the material by creating intense plastic deformations on the material surface. Equal channel angular compression molding (ECAP) was used for the severe plastic deformation process in our study. AA7075 alloy samples were primarily prepared for severe plastic deformation treatment. Then, the microstructural properties of the samples were investigated using various imaging techniques such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

The research results showed that significant microstructural changes occurred in AA7075 alloys after the severe plastic deformation process. The SPD process improved the mechanical properties of the material by transforming the crystalline structures of the material into a fine-grained structure. In addition, it was observed that deformation lines and pits occurred on the surface of the samples after the SPD process. It is seen that the SPD treatment increases the mechanical properties of the material such as strength, hardness and durability. Therefore, this study is an important step towards the development of the alloy's use in various industries.

1. INTRODUCTION

Compared to other materials, aluminum and its alloys have many excellent properties such as low density, high strength, good corrosion resistance, machinability, high thermal and electrical conductivity. Therefore, these materials are widely used in the aircraft and automotive industries. The use of high strength light metals is demanded in the aforementioned aircraft and automotive industry. The low density and corrosion resistance of aluminum and its alloys are important in terms of their use in many application areas [1, 2]. In addition, aluminum is extremely suitable for recycling. Al alloy is almost infinitely recyclable and the recycling process requires only 5% of the primary Al production energy [3]. High purity aluminum is a soft material with an ultimate strength of around 10 MPa, which limits its usability in industrial applications [4]. In order to compete with other building materials, the strength of Al-based materials must be increased significantly.

According to the American aluminum association, zinc is the main alloying element (containing between 1% and 8% Zn) of the 7XXX series alloys, which are classified in aluminum forging alloys, and is generally used with Mg, Cu and low rates of Mn and Cr to increase the strength more. They are heat treatable and show high strength. The 7XXX series is the highest strength of the aluminum alloys [5, 6]. It is used in aircraft fuselage structures, mobile equipment and other high-stress parts [7]. Copper alloys can be precipitation hardened. Depending on the alloy and method, there is a range of weldability from bad to very good. Among the 7XXX series alloys, the AA7075 alloy was introduced in 1943 as a result of intensive research. Commercial 7075 aluminum alloy belonging to the 7XXX series, which is one of the high strength aluminum alloys, is used as a building material in aircraft. This alloy is 5-6% Zn, 2-3% Mg, approximately 1.5% Cu and small amounts of Cr, Mn, Ti, Zr and Ag elements used to control crystallization behavior and modify precipitates [8].

Table 1 *Chemical Composition of AA7075 Alloy*

Alloy	***Si***	***Fe***	***Cu***	***Mn***	***Mg***	***Zn***	***Cr***	***Ti***	***Other***
7075	*0,4*	*0,5*	*1,2-2,0*	*0,3*	*2,1-2,9*	*5,1-6,1*	*0,18-0,28*	*0,06*	*0,25Zr +Ti*

Since the 90's of the last century, severe plastic deformation methods have been widely used for the processing of Al-based materials [9]. Severe plastic deformation, also known as severe plastic deformation, is known as plastic deformation of a metallic material by exposing it to large amounts of plastic stretching at low temperatures (below 0,3 times its melting temperature). Severe plastic deformation prioritizes the separation of

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coarse-grained microstructures, cell blocks, and dislocation cells into a hierarchical system. The most defining characteristic of all types of severe plastic deformation is that the cross-sectional area of the material remains constant after severe plastic deformation. Therefore, large amounts of plastic deformation are possible without a cross-sectional change because a sample can be subjected to excessive deformation many times for the plastic strain to multiply in its total amount. Severe plastic deformation methods,

1. Equal Channel Angular Pressing (ECAP), (also known as Equal Cross Section Lateral Extrusion - ECSLE)
2. It can be classified as cyclic extrusion and compression (Cyclic Extrusion Compression - CEC) and very fine structured materials can be obtained.

In these methods, the dimensions of the inlet and outlet sections of the deformed product do not change.

In the equal channel angular compression method, there are two equal sized channels intersecting each other at an angle of 90º, as seen in Figure 1 below. Here, the raw material is pressed by applying pressure with a stamp from one side of the desired channel and removed from the other end without changing its dimensions. Meanwhile, the material undergoes shear deformation. The process can be repeated several times to increase the amount of expansion and hence the plastic deformation [10].

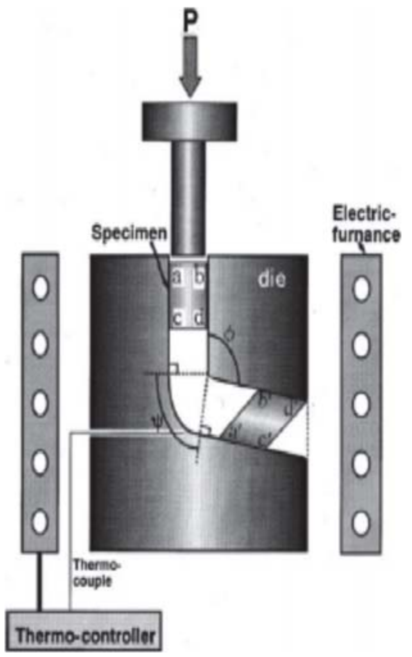

Fig. 1. Schematic view of the equal channel angular pressing method

2. EXPERİMENTAL WORK

In this study, changes in microstructural properties of AA7075 alloy before and after severe plastic deformation were investigated using various imaging techniques such as scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Table 2 *Chemical composition of the studied alloys in wt%*

Alloy	*Zn*	*Mg*	*Cu*	*Zr*	*Ti*	*Al*
AA7075	*6,6*	*2,3*	*1,7*	*-*	*-*	*Remaining*

In our study, an equal channel angular compression mold consisting of two equal sized channels intersecting each other at an angle of 90º was used. Since such operations are plane stretching operations, it does not matter whether the cross-section of the deformed material is a circle, square or other shape. Square mold is preferred because it is easy to machine. Aluminum alloys produced at certain temperature and pressure degrees are deformed by this mold. It is very difficult to reduce the grain size below 10 µm on average by recrystallization of aluminum alloys after thermomechanical processes. However, it is possible to reduce the grain size to less than 1 µm with excessive plastic deformation [11]. Force and distance will be recorded during deformation.

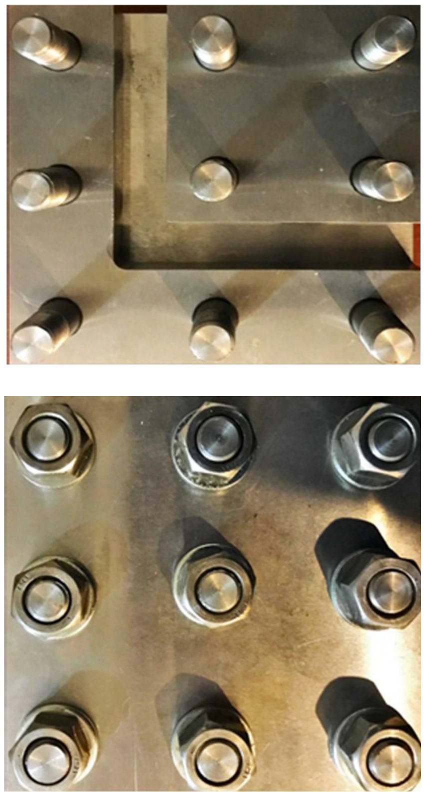

Fig. 2. Equal channel angular compression mold used in the experiments in open and closed states, top view

AA7075 alloy, SEM image before ECAP process is shown in Figure 3. The SEM image of the alloy deformed after ECAP process is shown in Figure 4. Alloys were etched with Dix-Keller reagent for 10 seconds to reveal the components.

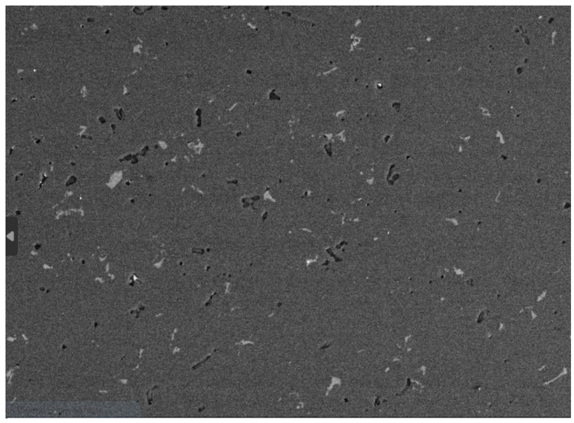

Fig. 3. SEM image of AA7075 alloy before severe plastic deformation

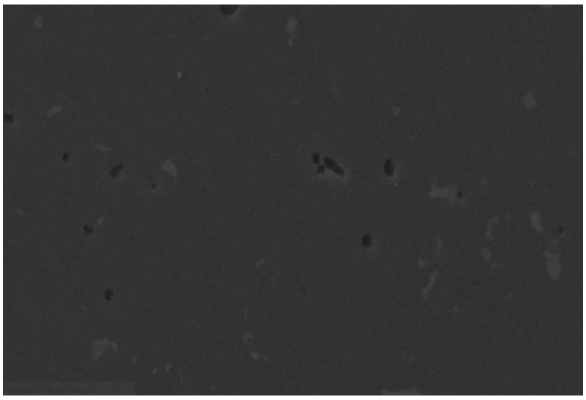

Fig. 4. SEM image of AA7075 alloy etched with Dix-Keller reagent after deformation process

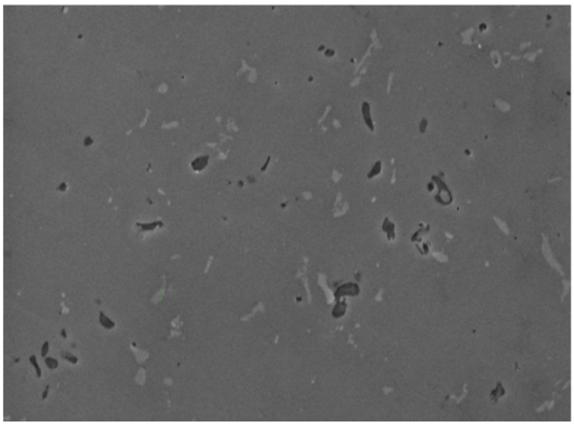

Fig. 5. SEM image of AA7075 alloy etched with Dix-Keller reagent after deformation process

3. CONCLUSION

Significant differences were detected between electron microscope (SEM) images of AA7075 alloys before and after severe plastic deformation. In the pre-deformation images, the microstructure of the alloy consists of dissolved and partially precipitated grains. Grains are generally large and irregularly shaped, with higher density in some areas. Among these grains, the matrix material and precipitation hardeners are not homogeneously dispersed. In the images after the severe plastic deformation process, the material grains are much smaller and evenly distributed. After the deformation process, the grains are generally small, uniformly shaped and have a homogeneous distribution. The precipitation hardeners are also more homogeneously dispersed. In addition, deformation bands and microcracks were formed in the material.

SEM images clearly show these microstructural changes. Since the grains are much smaller after the severe plastic deformation process, there are more grain boundaries, which increases the hardness of the material. Regulation of the grain size distribution reduces variation in material properties. Homogeneous precipitation hardener distribution is important for the hardness and durability of the material. Deformation bands increase the material's resistance to high microplasticity and deformation rates, while microcracks can affect material fatigue properties.

As a result, the microstructural changes of AA7075 alloys after severe plastic deformation process provide significant improvements in the properties of the material. These developments can cause the material to show higher strength, hardness and fatigue properties. However, some adverse effects such as microcracks that may occur during the excessive plastic deformation process should also be taken into account.

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